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Development and evaluation of symbology to identify individual dismounted soldiers

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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

The North Atlantic Treaty Organization (NATO) Land Capability Group 1 (LCG 1) has identified a need to develop and validate symbology for the individual soldier that can be displayed on a wide range of digital displays. Prototype symbology sets for this purpose have been developed by several NATO nations. A heuristic evaluation of these sets indicated that none of them were entirely consistent with good human factors practice. A new set (CHARLIE) was developed that conformed more closely to human factors guidelines. To further evaluate the most suitable symbology, an empirical assessment was carried out. Two different sizes of three prototype symbol sets were evaluated against backgrounds composed of digital photographic images of differing complexity and digitized paper maps under two different display resolutions. The symbol sets evaluated were the CHARLIE set discussed above, and two variants (ALPHA and BRAVO) of a set designed by NATO LCG1. The symbols were evaluated using a visual search task with accuracy and speed of response as the measures of performance. The results indicated that detection and discrimination of the CHARLIE symbols was significantly faster under all of the conditions tested and significantly more accurate with low resolution displays. Moreover, performance with the CHARLIE symbols was consistent across all the conditions tested (background, resolution, and symbol size).

Résumé

Le 1er Groupe sur les capacités terrestres (LCG 1) de l'Organisation du Traité de l'Atlantique Nord (OTAN) a cerné la nécessité de mettre au point et de valider une symbologie du soldat qui peut être affichée sur une vaste gamme d'écrans numériques. Plusieurs pays de l'OTAN ont développé des prototypes d'ensembles de symboles à cette fin. Une évaluation heuristique de ces ensembles a indiqué qu'aucun d'eux n'était tout à fait conforme aux bonnes pratiques ergonomiques. On a élaboré un nouvel ensemble (CHARLIE) qui respectait plus étroitement les lignes directrices de l'ergonomie. Pour évaluer davantage la symbologie la plus appropriée, on a procédé à une évaluation empirique. Deux tailles différentes de trois prototypes d'ensembles de symboles ont été évaluées sur des fonds composés d'images photographiques numériques de complexité différente et de cartes papier numérisées, selon deux résolutions d'affichage différentes. L'évaluation a porté sur l'ensemble CHARLIE susmentionné et sur deux variantes (ALPHA et BRAVO) d'un ensemble conçu par le LCG 1 de l'OTAN. On a évalué les symboles au moyen d'une recherche visuelle en utilisant comme mesures de rendement la précision et la vitesse de réponse. Les résultats ont indiqué que la détection et la discrimination des symboles CHARLIE étaient beaucoup plus rapides dans toutes les conditions d'essai et beaucoup plus précises avec des affichages à basse résolution. Par ailleurs, les symboles CHARLIE ont donné lieu à un rendement uniforme dans toutes les conditions d'essai (fond, résolution et taille des symboles).

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Executive summary

Development and evaluation of symbology to identify individual dismounted soldiers:

Sharon M. McFadden; Jeremy Robson; David Tack; DRDC Toronto CR 2010-152; Defence R&D Canada – Toronto; December 2011.

Introduction or background: The North Atlantic Treaty Organization (NATO) Land Capability Group 1 (LCG 1) has identified a need to develop and validate symbology for the individual soldier that can be displayed on a wide range of digital displays. Prototype symbology sets for this purpose have been developed by several NATO nations. A heuristic evaluation of these sets indicated that none of them were entirely consistent with good human factors practice. A new design concept (CHARLIE) was proposed that conformed more closely to human factors guidelines.

To further evaluate the most suitable symbology, an empirical assessment was carried out. The goal was to assess the detectability of two different versions (Small and Large symbols) of three prototype symbol sets against varied backgrounds, composed of digital photographic images of differing complexity and digitized paper maps, presented at two different display resolutions (high and low). The symbol sets evaluated were the CHARLIE set discussed above, and two variants (ALPHA and BRAVO) of a set designed by NATO LCG1. With ALPHA, affiliation and echelon were presented against a white background and with BRAVO, they were presented against the display background. The symbols were evaluated using a visual search task with accuracy and speed of response as the measures of performance.

Results: The results indicated that the CHARLIE symbols were detected and discriminated significantly faster under all of the conditions tested and significantly more accurately with low resolution displays. Moreover, performance with the CHARLIE symbols was consistent across all the conditions tested (background, resolution, and symbol size). However, response times did vary across the different symbols within the CHARLIE set.

Significance: The results of this study indicate that it is possible to design symbols that are legible under different display resolutions and visible against a wide range of backgrounds. However, the variability in performance across the different symbols suggests that discrimination could deteriorate as the number of different symbols on the screen increases.

Future plans: The first step is to extend the CHARLIE symbol set to represent all NATO soldiers. Once that is done, it will be necessary to re-evaluate the symbols to determine the effect of increasing the number of different symbols and methods for optimizing discriminability. In addition, it will be important to evaluate the utility of the proposed symbols.

Sommaire

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Introduction ou contexte : Le 1er Groupe sur les capacités terrestres (LCG 1) de l'Organisation du Traité de l'Atlantique Nord (OTAN) a cerné la nécessité de mettre au point et de valider une symbologie du soldat qui peut être affichée sur une vaste gamme d'écrans numériques. Plusieurs pays de l'OTAN ont développé des prototypes d'ensembles de symboles à cette fin. Une évaluation heuristique de ces ensembles a indiqué qu'aucun d'eux n'était tout à fait conforme aux bonnes pratiques ergonomiques. On a proposé un nouveau concept (CHARLIE) qui respectait plus étroitement les lignes directrices de l'ergonomie.

Pour évaluer davantage la symbologie la plus appropriée, on a procédé à une évaluation empirique. Le but consistait à évaluer la détectabilité de deux versions différentes (petits et grands symboles) de trois prototypes d'ensembles de symboles sur des fonds variés, composés d'images photographiques numériques de complexité différente et de cartes papier numérisées, selon deux résolutions d'affichage différentes (haute et basse). L'évaluation a porté sur l'ensemble CHARLIE susmentionné et sur deux variantes (ALPHA et BRAVO) d'un ensemble conçu par le LCG 1 de l'OTAN. ALPHA présentait l'affiliation et l'échelon sur un fond blanc, tandis que BRAVO les présentait sur le fond d'écran. On a évalué les symboles au moyen d'une recherche visuelle en utilisant comme mesures de rendement la précision et la vitesse de réponse.

Résultats : Les résultats ont indiqué que la détection et la discrimination des symboles CHARLIE étaient beaucoup plus rapides dans toutes les conditions d'essai et beaucoup plus précises avec des affichages à basse résolution. Par ailleurs, les symboles CHARLIE ont donné lieu à un rendement uniforme dans toutes les conditions d'essai (fond, résolution et taille des symboles). Les temps de réponse variaient toutefois entre les différents symboles dans l'ensemble CHARLIE.

Importance : Les résultats de cette étude indiquent qu'il est possible de concevoir des symboles lisibles selon différentes résolutions d'affichage et visibles sur un large éventail de fonds. Cependant, la variabilité du rendement entre les différents symboles laisse supposer que la discrimination pourrait se détériorer à mesurer qu'augmente le nombre de symboles différents sur l'écran.

Projets futurs : La première étape consiste à élargir l'ensemble de symboles CHARLIE de manière à représenter tous les soldats de l'OTAN. Ensuite, il faudra réévaluer les symboles afin de déterminer l'effet de l'augmentation du nombre de méthodes et symboles différents pour optimiser la discriminabilité. En outre, il sera important d'évaluer l'utilité des symboles proposés.

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Introduction

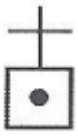
Background

Future soldier systems are being developed that can display a soldier's geo-location on a digital map or digital photograph, and present the resulting image through a helmet-mounted display, weapon sight display, portable digital assistant, mini-tablet, or laptop. Many nations intend to provide blue-force tracking on their hand-held soldier system computers so that the positions of all, or select members of a unit, can be observed in real time on the same digital map display.

A North Atlantic Treaty Organization (NATO) standard for military symbols for land systems (APP-6A) (North Atlantic Treaty Organization 1999) exists to provide common NATO operational symbology for interoperability of Land Command, Control, Communications, Computer, and Intelligence (C4I) systems. The conventions in NATO APP-6A are derived from MIL-STD-2525C (Department of Defense 2008). This standard provides a common symbol hierarchy, information taxonomy, and symbol identifiers, including a standard symbol set for all future NATO C4I operations in the force and engagement domains. Unfortunately, neither APP-6A nor MIL-STD-2525C includes symbology to identify individual soldiers. Consequently, NATO Land Capabilities Group 1 (LCG 1) has identified a need to develop and validate a standard NATO symbol set that cover all NATO dismounted soldier roles.

Several NATO nations have developed soldier-level symbology for their own purposes. Example symbols, from the sets that were provided to LCG 1 for evaluation, are shown in Table 1. In addition, LCG 1 also put forward a design concept that was similar to, but more extensive than, set 6. Examples of all the available symbols are shown in Annex A. None of the proposed symbol sets had been systematically evaluated. At the request of LCG 1, Defence Research and Development Canada (DRDC) – Toronto undertook a project to systematically assess these existing sets in order to validate the selection of either an existing set, a modified version of an existing set, or a new set that better complies with human factors guidelines.

Table 1: Examples of symbols proposed by different NATO nations

Symbol set	Sample symbol	Number of available symbols
1		2
2		8
3		3
4		4
5		2
6		7

Evaluation framework

As a first step, a framework was developed to evaluate the existing symbol sets. To avoid bias, the framework was based on international standards[1]. It was designed to meet the following criteria:

- Military domain – any candidate symbol set must uphold the design conventions (particularly Land Force) that have long been in practice in NATO nations and be effective in the military domain in which they will be used.
- Human factors domain – any candidate symbol set must meet human factors criteria for symbol design to ensure optimum detectability, legibility, and usability.
- Adaptability to digital displays – candidate symbols should be usable on a wide range of display technology with different physical parameters.

[1] For a list of the standards reviewed, see Tack, Robson and Matthews (2009).

Together, these three domain areas were believed to encompass the broad range of symbol set usability and employment issues for small unit army applications.

Military domain

APP-6A sets out a number of symbol design conventions that need to be maintained in any future soldier symbology. These include the frame shape, affiliation, status, fill, interior icons, and modifiers for movement, echelon, equipment, and so on. Specific guidance is provided for symbol framing, placement of icons and modifiers and design specifications are provided for size, shape, orientation, colour, line width, and so on. It is important that any symbols representing individual soldiers be consistent with these existing criteria to simplify learning and avoid confusion.

In addition, it was determined that to provide a comprehensive set of symbols for soldier identification at Company level and below, it was important to include symbols that incorporated the following dimensions:

- Role: military function of the individual, e.g., commander, fire team leader.
- Echelon: Military operational unit, e.g., company, platoon, section, squad.
- Affiliation: The unit and sub-unit that employs the soldier.

Using all three dimensions enables a symbol to specifically identify almost any soldier on the battlefield, assuming an intra-section naming convention for soldiers within each sub-unit.

Finally, the context in which the symbols will be presented was considered. Operations are increasingly occurring in built up areas with complex terrain. This introduces more complexity into the digital maps and satellite photographs that will likely form the backgrounds of map displays in future soldier systems. As well, it will be possible to superimpose a wide range of data on these backgrounds. This will lead to maps being cluttered with many different symbols for friendly and enemy forces, equipment and structures. It is important that the visibility of the symbols not be reduced by background clutter or because of similarity to other critical information.

Human factors domain

A wide range of standards have been developed by industry and government to support the design of symbols and icons. Based on a review of these, especially EG 201 379 V1.1.1 (European Telecommunication Standards Institute 1998), the following human factors criteria were determined to be important in evaluating the utility and usability of symbols:

- Comprehensibility – the ease with which the meaning of the symbol is understood.
- Discriminability –the ease with which a given symbol can be distinguished from other symbols that might occur in close spatial, temporal or contextual proximity.
- Learnability – the ease with which the meaning of a symbol can be recalled after it has been understood.

- Legibility – the ease with which the figural detail of a symbol can be discerned.
- Recognisability – the ease with which it is possible to identify a symbol based on previous experiences with the same or similar types of symbols.

Adaptability to digital displays

It is likely that the proposed soldier symbology will be displayed on a wide range of displays with different characteristics including screen resolution, screen size, and technology. ISO 80416-4 (International Standards Organization 2005) was used to derive digital display evaluation criteria and provided guidelines for the adaptation of symbols to screens and displays for a wide range of equipment and devices. Specifically, issues associated with symbol size, pixel grids, degradation of resolution, and use of colour were considered.

Evaluations

With the possible exception of the LCG1 set, none of the symbol sets included symbols for all of the NATO roles and echelons. This made it difficult to conduct a systematic empirical evaluation. In addition, it would have been time consuming to run an empirical study that compared all of the symbols against the framework. Thus the evaluation was divided into two parts. Part 1 involved a heuristic evaluation of each of the available symbols sets. As a result of this evaluation, a new design concept was proposed that more closely conformed to the criteria used in the heuristic evaluation. Part 2 involved an empirical evaluation of the new symbol set against the symbol set proposed by LCG1. It was chosen because it included the widest range of symbols.

Part 1: Heuristic evaluation

Method

For the heuristic evaluation, specific criteria were extracted from the standards and guidelines used in developing the heuristic framework under the three domains discussed previously. Each symbol set was then evaluated by three human factors experts against each of these criteria using a five point scale. The specific criteria assessed under each of the three domains in the evaluation framework were as follows:

- Military criteria

    1. All symbols within the set conform to a rectangular "ground" shape as per the aspect ratios of MIL-STD-2525C (Department of Defense 2008) (i.e. ratios of 1:1, 1:1.5).
    2. Symbols have an appropriate frame border width.
    3. Symbols use both shape and fill colour to indicate battle dimension.
    4. Symbol friendly interior elements can be recognizable at the smallest expected symbol size.
    5. Symbol interior elements can be recognizable at the smallest expected symbol size for the following affiliations: red (hostile and suspect), yellow (unknown), cyan (friendly) and green (neutral).
    6. The frame indicates the location status (actual versus planned) of the soldier at the smallest expected symbol size.
    7. Symbols are universally consistent with NATO echelon conventions.

- Human factors criteria

    1. Role symbols are discriminable from each other.
    2. Symbols maintain their integrity when clustered together (not overlapped).
    3. Symbols convey required information with fewest elements.
    4. Symbols are replicated easily (i.e., drawn by hand on paper).
    5. Symbols are readily discernable from a temperate map background.
    6. Symbols are readily discernable from an arid map background.
    7. Symbols are readily discernable from highly textured map background (lines, buildings, etc).
    8. For discrete icons there is a clear gap between the icon and the surrounding border at the smallest usable size.

9. Symbol can accommodate worst-case overlapping direction without loss of discernability.

- Digital display criteria

1. The role of symbols can be discriminated from each other at smaller sizes and at lower resolutions.
2. The echelon of symbols can be discriminated from each other at smaller sizes and at lower resolutions.
3. The unit affiliation of symbols can be discriminated from each other at smaller sizes and at lower resolutions.

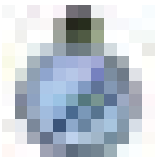
To assess criteria 5 to 7 in the human factors domain, representative symbols were superimposed on digital imagery of varying complexity and digitized maps. To assess the symbol sets against the digital display criteria, a complex example symbol from each set was adjusted in size and resolution (Table 2 provides an example). For size, the symbols were adjusted to fit into squares of the following dimensions:

- 20mm x 20mm
- 15mm x 15mm
- 10mm x 10mm
- 5mm x 5mm

For resolution, symbols were graphically re-sampled into the following four pixel grids, as suggested by ISO 80416-4 (International Standards Organization 2005):

- 64 x 64 pixels
- 32 x 32 pixels
- 16 x 16 pixels
- 12 x 12 pixels

Table 2: Sample symbol at each combination of size and resolution used in the evaluation

		Resolution (pixels)			
		64X64	**32X32**	**16X16**	**12X12**
Size (mm)	**20X20**				
	15X15				
	10X10				
	5X5				

Results

The results for the three sets of criteria, military, human factors, and display, are shown in Figure 1. Given the quality and quantity of data, any type of statistical analysis would be inappropriate. For the first two factors, scores for each set were summed to give a general measure of goodness-of-fit. For the display domain, individual scores are shown. Neither set 1 nor set 4 contained any interior elements. As a result, they could not be evaluated on criteria 4 and 5 under the military domain nor criterion 8 under the human factors domain. To assess the impact of this difference, scores with and without these criteria were computed for the remaining candidates. In general, removing these questions tended to reduce the average scores on the military criteria, but had no effect on the average scores for the human factors criteria. Thus for the military criteria total score with and without these questions have been computed, and for the human factors criteria, criterion 8 has not been included in the total score.

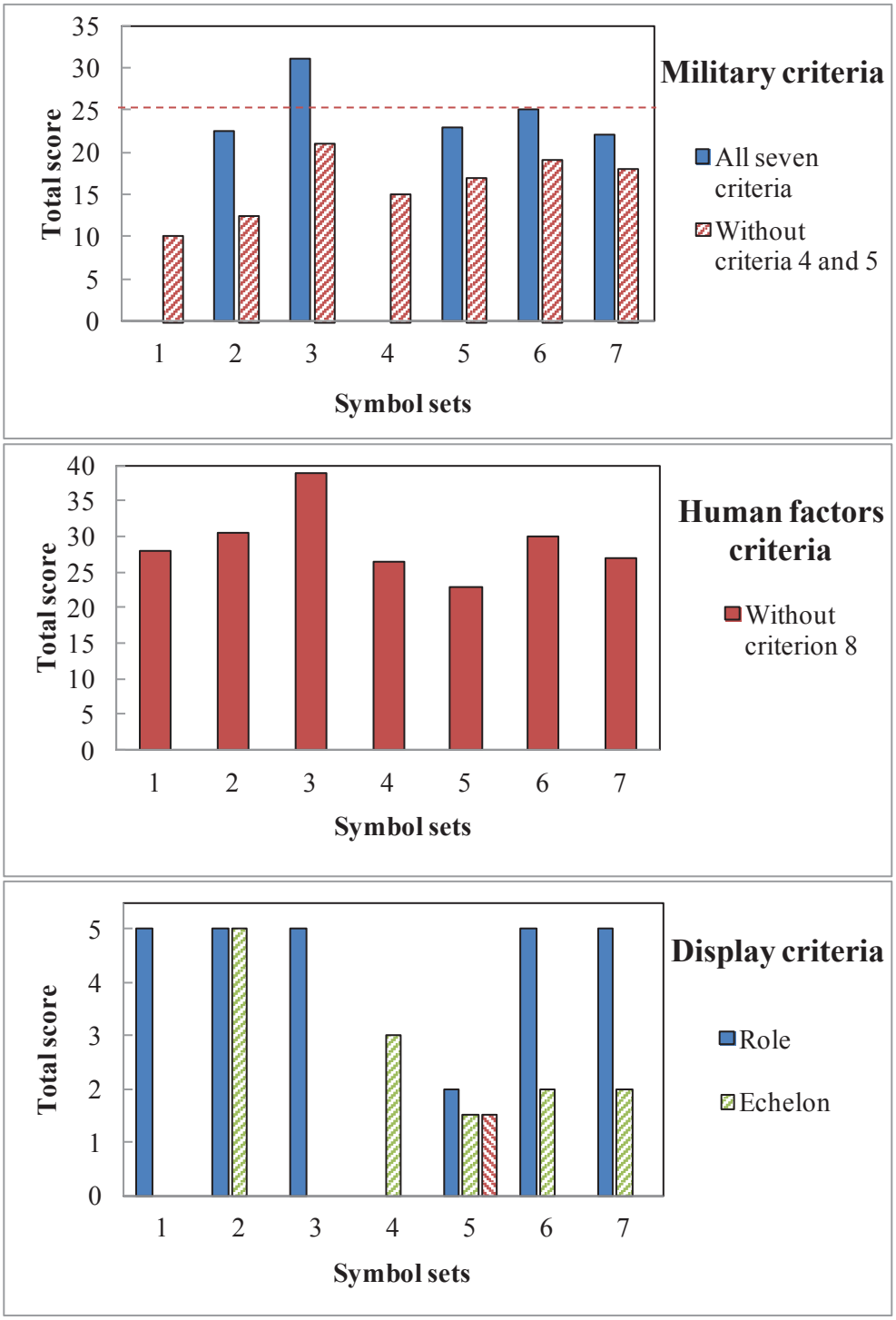


Figure 1: Scores for the existing symbol sets on the military, human factors, and display criteria. The dotted line indicates a perfect score for five military criteria.

The display criteria focused on the discriminability of role, echelon, and affiliation information. Unfortunately one symbol set did not provide role information; two did not provide echelon information, and only one included affiliation information.

As can be seen, symbol set 3 tended to perform best. In addition to locating all components inside the framework, it complied most closely with APP-6A / MIL STD 2525C. Unfortunately, it does not address the challenge of covering the required range of echelons and affiliations. Symbol set 5 tended to perform the poorest across all three areas. Unlike the other sets, it employs a complex torso shape instead of a simple geometric shape. The torso shape leaves less room for echelon and affiliation information. On the other hand, it was the only symbol set that included role, echelon, and affiliation information. The primary weakness with all but set 3 was the use of text and or lines outside the framework. Text and lines may become confused with background features especially in urban maps and satellite imagery.

Proposed symbol set

As a result of the problems, discussed in the previous paragraph, with the existing symbol sets, it was decided to develop a concept for a symbol set that would more closely conform to the heuristic framework. Thus, as shown in Table 3, the symbols met the following design criteria:

- Symbol shape and in-fill: Symbols have a rectangular shape with a clear frame border and light blue in-fill as per APP-6A.
- Role: Officers are denoted by a regular frame while enlisted soldiers are denoted by the addition of angled corners. In sourcing a way to denote enlisted positions, the rank insignia for a range of NATO nations was consulted. The characteristic of most enlisted rank insignia is a chevron or angled tabs. The angled corners of the enlisted symbols give the illusion of a chevron over the blue in-fill.
- Echelon: Echelon is represented using the same convention as APP-6A, as indicated in Table 4 below.
- Affiliation: Unit affiliation is indicated by the convention of "unit of sub-unit". For example, 1-3 denotes 1 Platoon, 3 Section. Soldier members of a Section/Squad, not including the Section Commander or Second in Command (2i/c), would be denoted by a single number to reflect their position.
- Clutter and Overlap: All soldier identity information is contained within the symbol frame to avoid any loss of discernability due to background clutter and to minimize any information loss due to symbol overlapping.

The new symbol set concept design was scored using the analytical framework and generated a near-perfect score. The design only lost points for discernability of affiliation at the lowest resolutions and sizes, suggesting that some fine tuning of numeric text fonts is required.

Table 3: Proposed concept for a symbol set

NATO position	Symbol concept
Company Commander	
Company Second-in-Command	
Fire Team Leader	
Platoon Commander	
Platoon Sergeant	
Section Commander	
Section Second-in-Command	
Soldier	

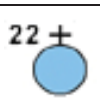
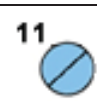
Table 4: NATO APP-6A echelon icons

Indicator	Description
Ø	Team/Crew
•	Squad
••	Section
•••	Platoon
|	Company

Part 2: Empirical evaluation

Since the new design concept was based on the heuristic framework, it was not surprising that it scored better than the remaining design concepts in the heuristic evaluation. The next step was to conduct a more objective evaluation. One of the limitations of the previous comparison was that the symbol sets varied in the range of roles and echelons they included. Ideally, we wanted to evaluate as rich a symbol set as possible in order to assess the discriminability of the individual symbols within a set. Of the symbol sets originally evaluated, only symbol set 7, developed by LCG1, covered the same range of roles and echelons as the proposed symbol set. However, even it did not include a concept for affiliation. To overcome this limitation, a design concept consistent with APP-6A was used; namely, affiliation was specified using text in the upper left corner of the symbol outside its frame. Two different variants were evaluated: ALPHA which placed the affiliation and echelon information against a white background in accordance with NATO's design guidelines (North Atlantic Treaty Organization 1999) and BRAVO which followed MIL-STD-2525C. The proposed symbol set was labelled CHARLIE.

Table 5: Examples of the symbols used in the evaluation.

	Platoon Com-mander	Platoon Sergeant	Section Com-mander	Section Second in Command	Company Com-mander	Company Second in Command	Fire Team Leader
ALPHA							
BRAVO							
CHARLIE							

The actual symbols used in the experiment are shown in Table 5. The design concept for the CHARLIE symbols has been described earlier. For BRAVO and ALPHA, role is indicated by the presence (enlisted role) or absence (officer role) of one or more diagonal lines inside the blue circle. Echelon is denoted by lines and cross lines extending above the circle and affiliation by the convention of unit of sub-unit (e.g. 13 indicates the soldier is a member of One Platoon, Three Section) beside the echelon component[2].

[2] It should be noted that the symbol sets under evaluation are prototypes and the design concepts used in their construction may not be applied consistently across all symbols. Further development, aided by the results of this study, is required to produce symbols that cover the roles, echelons and affiliations of all NATO soldiers.

To assess the discriminability and recognisability of the three design concepts, performance was measured using two variants of a visual search task. In both tasks, observers were required to search for a specified symbol in a background of distractor symbols. In the first task, the distractor symbols always differed in either role or echelon. Thus if the target was Platoon Commander 1-3, none of the distractor symbols represented a Platoon Commander from a different unit or sub unit. In the second task, some of the distractors differed from the target symbol only in unit and/or sub unit.

While both tasks assessed discriminability and recognisability, the latter task also assessed legibility. To further assess legibility, the study examined performance at two different symbol sizes and two different display resolutions. The smaller symbol size was based on the outcome of the heuristic evaluation (Tack et al. 2009). The larger symbol size was included to determine the advantage/disadvantage of increasing symbol size even further. While a larger symbol may be more visible against a complex background, it can also result in more frequent symbol overlap. To minimize symbol overlap, the increase was limited to 20%. Since these proposed symbols are likely to be displayed on a wide range of technologies, it is important that the symbols remain legible at different display resolutions. Thus, performance was assessed at two display resolutions. The high resolution condition (72 pixels per inch) was equivalent to a standard, 1024 by 768, monitor. The lower resolution (50 pixels per inch) approximated a smaller, lower resolution, 640 by 480, monitor.

The final variable assessed in the current study was background. The backgrounds used in future soldier systems are likely to vary from very simple, e.g., desert and rural areas through to complex urban environments with high density of buildings, roads, and other structures as well as digitized conventional maps. Moreover, the results of the heuristic evaluation indicated that the visibility of the external modifiers used to define echelon with ALPHA and BRAVO was reduced when the symbols were presented against a complex background. For that reason, the symbol sets were evaluated against three types of backgrounds: Simple, Complex, and Map. Simple backgrounds were digital photographs that had little variation in colour or texture, and contained few buildings, roads etc. Complex backgrounds were also digital photographs, but they had more variability and irregularity through increased colour differentiation, less regularity in terms of physical features (roads, buildings, topography etc), greater contrast, and more buildings. Map backgrounds consisted of digitally scanned military paper maps.

Method

Participants

Twenty-five volunteers, 11 males and 14 females, participated in the experiment. They ranged in age from 18 to 60 with a mean age of 25.5. Participants were required to self identify that they had normal colour vision and normal or corrected to normal visual acuity.

Experimental Design

For the first (detection) task, a 3 (symbol set) by 3 (background type) by 2 (symbol size) by 2 (display resolution) factorial design was used. Each of the seven target symbols within each set was presented against three different types of background - Simple, Complex and Map. Two

symbol sizes were used for each symbol set: Small symbols (defined using a heuristic (Tack et al. 2009)) and a second set of symbols 20% larger than the Small symbols and referred to throughout this report as Large. Finally, the backgrounds and symbols were presented at two different resolutions, HR (72 pixels per inch) and LR (50 pixels per inch).

Participants completed a run of 7 trials under each combination of symbol set, resolution, symbol size, and background for a total of 252 trials. On each trial in a run, one of the seven symbol shown in Table 5 (e.g., Platoon Sergeant (1-3) or Fire Team Leader (2-2)), for the symbol set under study in that session, was selected as the target. It was presented together with 19 distractor symbols. The distractors were randomly selected from the remaining symbols in that set with the restriction that they could not have the same role and echelon as the target symbol (See Annex B for examples of all possible symbols that might appear as distractor symbols). The target symbols on each of the 7 trials represented a different symbol role and/or echelon and the order of presentation of the different target symbols was randomly varied across the different conditions and participants.

For the second (legibility) task a 3 (symbol set) by 3 (background type) by 2 (symbol size) factorial design was used. Due to limitations in time and resources, it was not carried out in the low resolution condition. Otherwise, the legibility task was identical to the detection task except that symbols representing the same role and echelon as the target symbol, but with different affiliation information, were included among the distractor symbols. For example, if the target symbol was Fire Team Leader 1-1, the display would also feature the symbols for Fire Team Leader 2-2. The purpose of this second run was to measure the legibility of the modifier information on the symbol (e.g., 1-1). As will be noted in Table 5, the instantiation of this information varied considerably across the three symbol sets.

Presentation order of the three symbol sets was randomized across participants and each symbol set was presented on a different day. The order of the remaining conditions was fixed (see Table 6). Given the relatively small number of trials, it was decided that it was preferable to present first those conditions in which the symbols were likely to be the most discriminable.

Table 6: Presentation order of the different conditions for each symbol set.

Resolution	Symbol size	Background	Number of trials
HR	Large	Simple	7 detection
			7 legibility
		Complex	7 detection
			7 legibility
		Paper map	7 detection
			7 legibility
	Small	Simple	7 detection
			7 legibility
		Complex	7 detection
			7 legibility
		Paper map	7 detection
			7 legibility
LR	Large	Simple	7 detection
		Complex	7 detection
		Paper map	7 detection
	Small	Simple	7 detection
		Complex	7 detection
		Paper map	7 detection

Apparatus

The apparatus comprised a standard "Windows" workstation with a 19" colour screen, a mouse and keyboard. Participants were also provided with a work surface to record notes, and an ergonomically designed operator's chair.

Stimuli

The stimuli were the symbols in the three symbol sets, ALPHA, BRAVO and CHARLIE, shown in Annex B. Each symbol shows the role, echelon, and affiliation of a dismounted soldier. The Small ALPHA symbols were 8mm wide by 7mm high and the Large were 9 by 8mm. Small BRAVO symbols were 7mm wide by 7mm high and the Large were 8 by 8mm. The Small CHARLIE symbols were 8mm wide by 6mm high and the Large were 10 by 8mm.

Three different types of background were used in the experiment - Simple, Complex and Map. Simple backgrounds were digital photographs of rural areas. They had little variation in colour, shading, or geometry and featured very few buildings or roads, if any. Typical images included fields, meadow, desert and scrub. Complex backgrounds were provided by digital photographs of major conurbations. They featured extensive colour variation, light and shading, with a variety of buildings of different shapes and sizes. Complex backgrounds typically included major highways and varied between suburban and downtown areas as well as industrial zones including warehouses and plants. All images used for the Simple and Complex backgrounds were presented at a scale of 1-25000 feet. Map backgrounds were digitally scanned military paper maps used by Canadian and Norwegian land forces and the US Marine Corps. The maps were shown at the same scale (1-25000 feet) as the photographs.

The backgrounds used in the experiment were created by selecting small sections from a few large images and maps and presenting them either in their original orientation or rotated 90 or 180 degrees. With this process, it was possible, with one exception, to present a slightly different background on almost every trial while maintaining backgrounds of similar complexity across all trials in each background type. The exception was that the same images were used in equivalent HR and LR trials (e.g. the same Complex background would be used for the Large CHARLIE symbol, Company Commander, in the HR and LR conditions). This was done because of the limited time available to generate all of the stimuli. For each HR trial, 19 distractor symbols, randomly selected from the target symbol set, were randomly place on a background. This image, background plus symbols, was then saved. For the equivalent low resolution condition, each image was edited to mimic the effect of a lower resolution screen (50 pixels per inch or 20 pixels per cm as opposed to 72 pixels per inch or 28 pixels per cm) while keeping the image size in the two resolutions equal. All images had a diagonal width on the screen of 18.2 cm. Examples of the symbols and backgrounds are shown below in Figures 2 through 4.

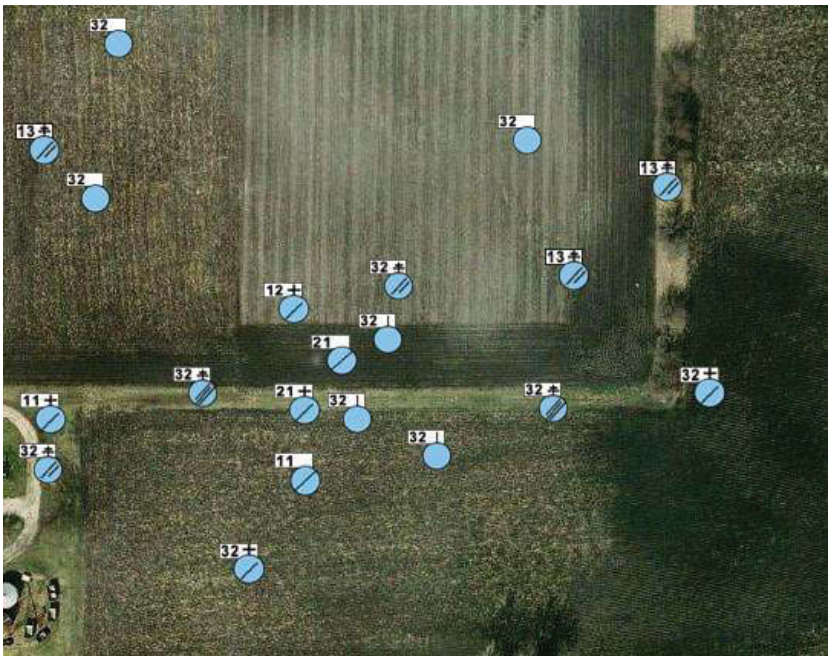


Figure 2: Example of the Small HR ALPHA symbols against a HR, Simple background.

Figure 3: Example of Large LR BRAVO symbols displayed against a LR Complex background.

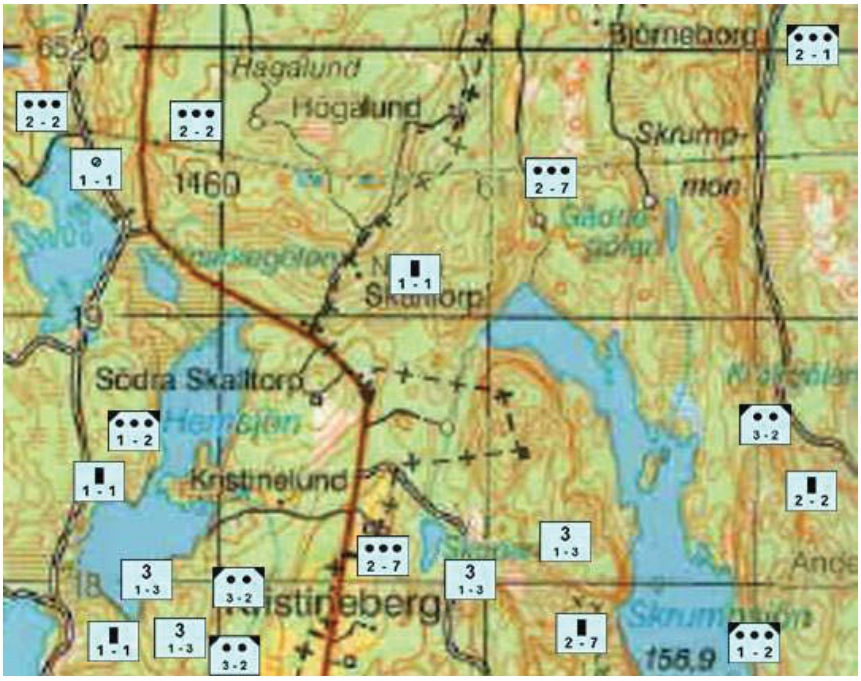


Figure 4: Example of HR Small CHARLIE symbols against a HR Map background.

Task

The participant's task on each trial was to identify the target symbol as quickly as possible using a mouse to position a cursor over the symbol they thought was the target and clicking the left mouse button.

Procedure

The experiment was conducted over three sessions with a different symbol set (ALPHA, BRAVO, or CHARLIE) being evaluated on each day. The room was illuminated using a mixture of artificial light (from ceiling lights and through a single glazed door). Four workstations were set up with dividers separating the participants. Viewing distance to the screen was approximately 50 cm.

At the start of the first session, participants were given an orientation briefing on the overall study, its objectives, and what they would be asked to do. They were also given a sheet containing all the relevant target symbols for the current session. Following the initial briefing, they were asked to read an information sheet about the study and to complete an informed consent form The protocol followed for this experiment was approved by the DRDC Ethics Committee (Protocol number: L725). After participants had completed the preliminary paper work at the start of the session, they were informed that they could take a short break during any natural break in the test session (i.e., when the next set of stimuli was being configured by the experimenter).

Following the briefing, participants were trained to recognise all of the symbols within the set that they would be tested on during that session using a series of PowerPoint slides. The training culminated in an assessment of the participants' ability to readily recognise each of the seven symbols within a particular symbol set. When participants felt confident that they could readily recognize all seven symbols within the set, they moved on to the experimental phase of the study. Training was repeated as and when necessary to ensure that the participants had reached an appropriate threshold of knowledge. However, the ability to readily recognize each symbol was not critical as a table with each of the symbols (with example modifier information) was displayed on the screen while participants were carrying out the task.

The experimental software package RESOLVE, (developed by Array Systems) provided the platform for the experiment. At the start of each trial, the software presented a statement such as, "Find the Company 2i/c (1-3)," together with an example of the target symbol (Figure 5).

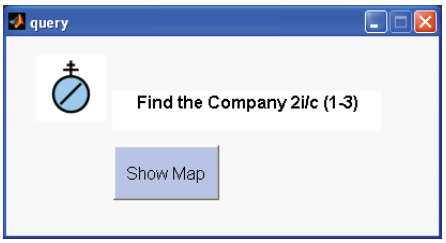


Figure 5: Example of the screen presented at the beginning of each trial.

When the participant was ready, he or she would position the cursor on the "Show Map" button and click the left mouse button. This brought up a display containing that target. Once the target had been selected, the test screen disappeared and the next target statement appeared. Participants' responses (hits and misses) and speed of response were recorded by RESOLVE in an Excel spreadsheet.

At the end of each experimental session, participants were presented with a series of examples (individual or group), from the relevant symbol set, which they were asked to identify to assess the extent to which they had learned the symbols.

Statistical analysis

The results of interest were accuracy and response time per trial. Since the response times were somewhat skewed (skewness was greater than 2 across most conditions), $\log_e$ response times were used in all the analyses reported in the paper. Often in visual search tasks, only the response time of correct trials are analysed. Since participants were required to select a symbol on each trial, the distribution of response times for correct and incorrect trials was similar. Thus, all response times were included in the analyses. In addition to the separate analyses of accuracy and $\log_e$ response time, multivariate analyses of log response times and accuracy combined were also carried out. The Pillai's Trace statistic is reported for the multivariate analysis because it proved to be the most conservative estimate of significance. The multivariate analyses allowed us to assess any trade-off between accuracy and response time. For all statistical tests, a significance level of 0.01 was used. The Scheffe test was used for post-hoc tests in the univariate analyses. Separate repeated measures ANOVAs were carried out on the detection and the legibility data.

Results

The main purpose of this study was to compare the detectability, discriminability, and legibility of the three symbol sets. The remaining variables were included to determine how detection and discrimination might be affected by the display characteristics; performance was assessed at different display resolutions, symbol sizes and backgrounds. Thus, the results will focus on the effect of symbol set on accuracy and response times and the interactions between symbol set and the remaining variables. Performance on the two tasks are analysed separately.

Detection performance

As can be seen in Table 7, all of the independent variables, symbol set, resolution, symbol size and background, had a significant effect on both accuracy and response time for the detection task. In addition as shown by the results of the multivariate analysis, all of the independent variables had a significant effect on accuracy and response time combined indicating that there was no trade off between accuracy and response time. In general, performance was significantly more accurate and faster with the CHARLIE symbols than with the ALPHA and BRAVO symbols. As well, performance was better in the HR condition than the LR condition and with the Large symbols. The overall effect of background was relatively small. However, as Table 4 also shows, there were several significant two- three- and four-way interactions. Some of the higher order interactions might have been affected by the fact that the order of the different conditions

(with the exception of symbol set) was not randomized across participants. Since the interactions may mitigate the main effects, the result section focuses on the significant three-way interactions.

Table 7: Summary of repeated measures analyses of variance for symbol set including significant interactions with resolution, symbol size, and background. Results for accuracy, response time, and a multivariate analysis of both measures are shown. Column 2 shows the univariate and multivariate degrees of freedom.

Condition	Univariate / multivariate degrees of freedom	F values ($p < 0.01$)		
		Accuracy	Response time	Multivariate
Symbol set (SS)	2,48 / 4,96	40.5	189.6	21.6
Resolution (R)	1,24 / 2,23	74.4	73.9	74.1
Symbol size (SZ)	1,24 / 2,23	21.1	9.6	11.0
Background (B)	2,48 / 4,96	5.6	15.7	7.6
SS * R	2,48 / 4,96	39.0	17.7	15.7
SS *SZ	2,48 / 4, 96	n.s.	n.s.	n.s
SS*B	4,96 / 8,192	7.5	8.9	8.4
R*SZ	1, 24 / 2,23	27.4	n.s.	14.7
R*B	2,48 / 4,96	n.s.	10.9	6.0
SZ*B	2,48 / 4,96	n.s.	n.s.	n.s.
SS*R*SZ	2,48 / 4,96	7.2	n.s.	5.9
SS*R*B	4,96 / 8,192	12.2	5.1	5.7
SS*SZ*B	4,96 / 8,192	7.9	n.s.	4.3
R*SZ*B	2,48 / 4,96	6.5	13.9	6.5
SS*R*SZ*B	4,96 / 8,192	5.5	n.s.	3.9

The interaction between symbol set, resolution, and background is shown in Figure 6 for both accuracy and response time. As indicated, accuracy and response time for detection of the CHARLIE symbols does not tend to be affected by either resolution or background. Moreover, response time is much faster for the CHARLIE symbols than for either the APLHA or BRAVO symbols. For both the ALPHA and BRAVO symbols, detection tends to be more accurate and faster in the HR conditions. However, the interaction between resolution and background tends to be somewhat different for the two symbol sets. With the ALPHA symbols there is a moderate but consistent decrement in performance across all three backgrounds. With the BRAVO symbols, performance is similar in both the HR and LR conditions against a Simple background, but resolution has a very large effect on both accuracy and response time with the Map and Complex backgrounds.

As well, Figure 6 illustrates the two-way interactions between symbol set and resolution, symbol set and background, and resolution and background. In general, the two way interactions involving symbol set can be explained by the fact that only the ALPHA and BRAVO symbols are affected by either resolution or background with resolution having a much stronger effect than background. In the HR conditions, accuracy is similar across all three symbol sets, but response

time is still significantly faster with the CHARLIE symbols. In terms of the two way interaction between resolution and background, the effect of resolution appears to be greater with the Map and Complex backgrounds. As discussed above, this is largely confined to the BRAVO symbol set.

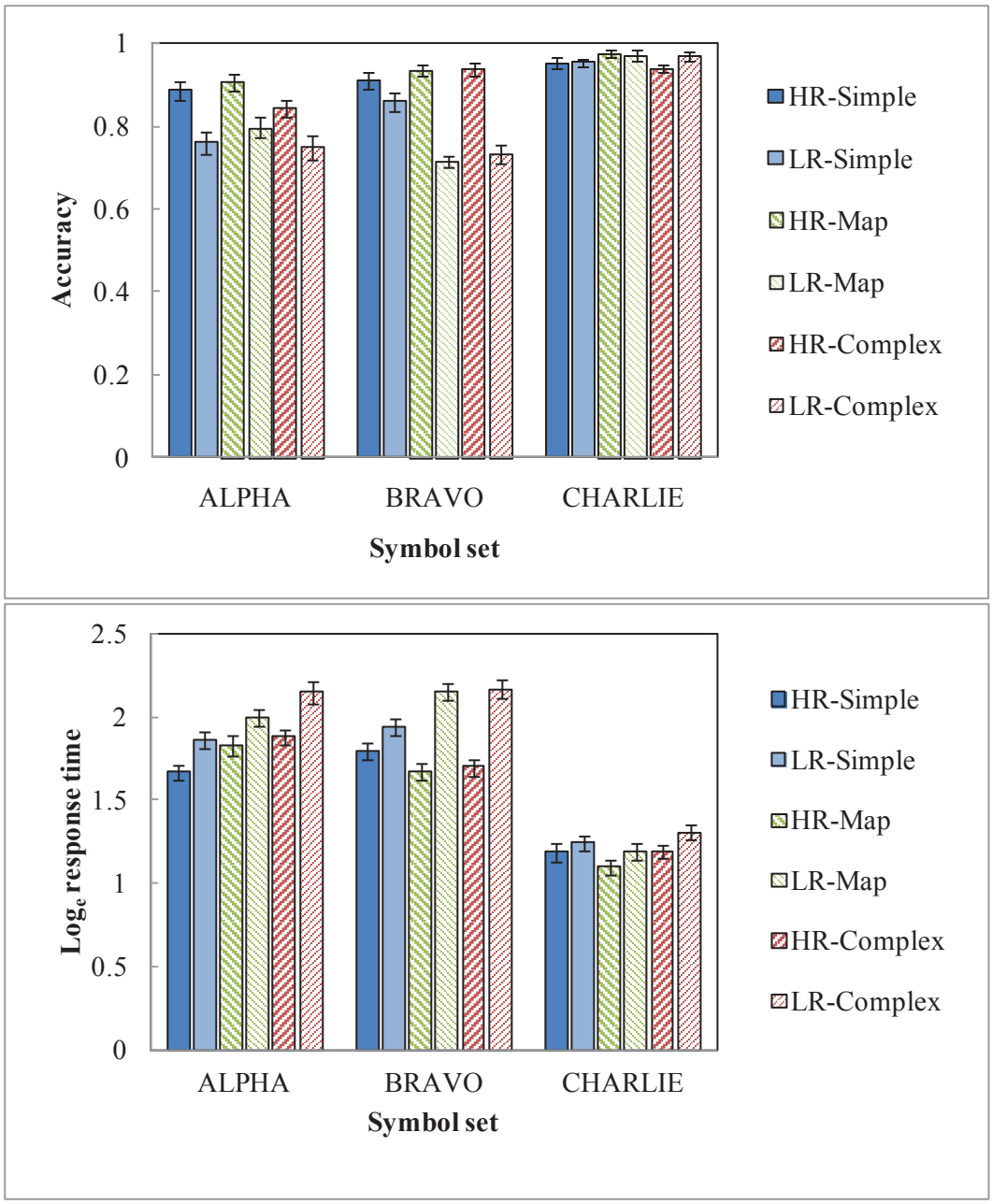


Figure 6: Accuracy and log$_e$ response time for the three symbol sets as a function of resolution and background. The standard error bars are also shown in this and subsequent figures.

As with the previous interactions, any effects of symbol size were limited to ALPHA and BRAVO (Figure 7). In addition, the effects of symbol size tended to be limited to accuracy. With the three-way interaction across symbol set, resolution and symbol size, the decrement in accuracy in the LR condition is mitigated somewhat by the use of Large symbols for ALPHA and BRAVO.

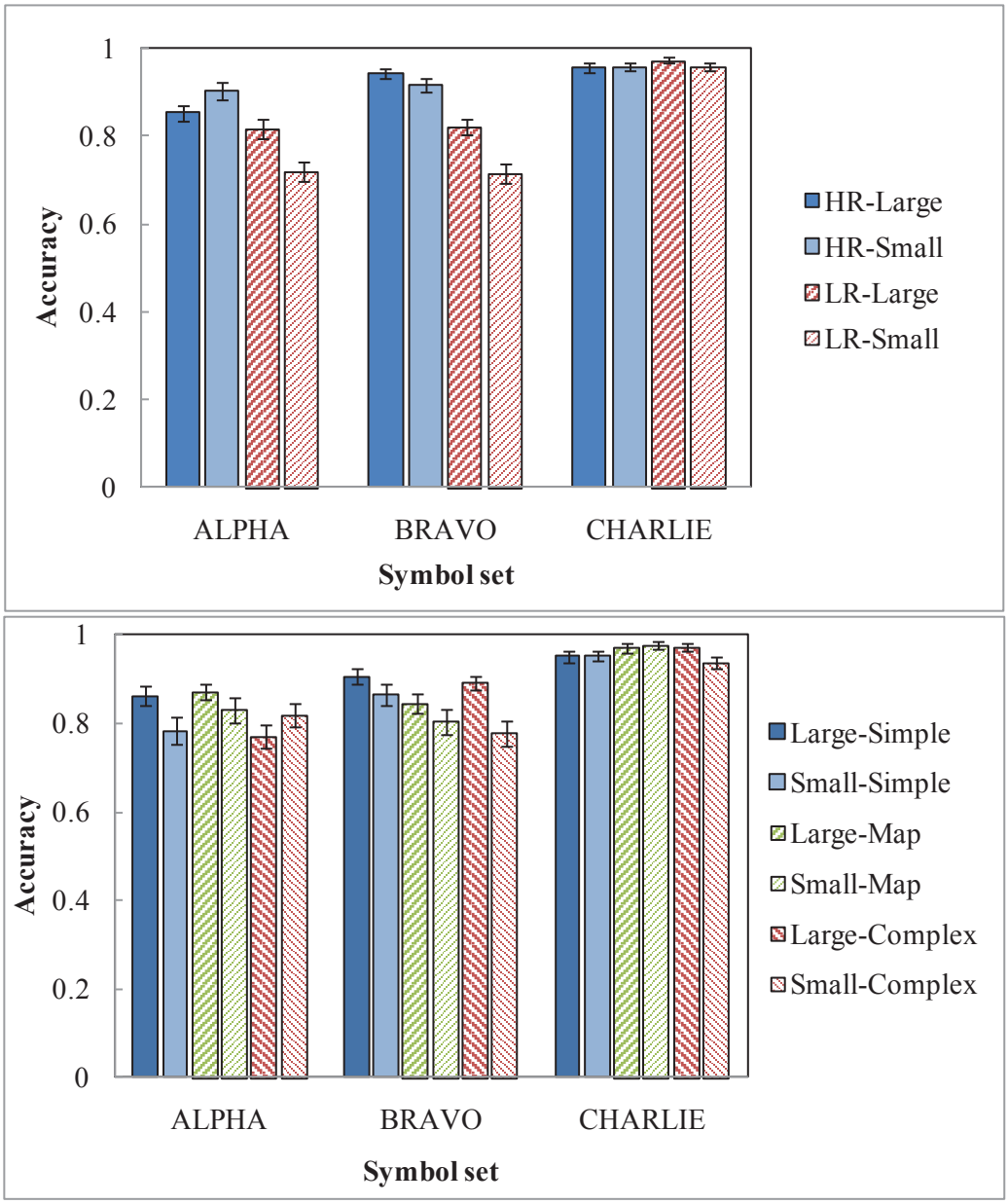


Figure 7: Response accuracy for the three symbol sets as a function of a) resolution and symbol size and b) symbol size and background.

The three-way interaction across symbol set, background, and symbol size for accuracy (Figure 7b) is probably due to the inconsistent effect of symbol size across the three backgrounds for the

ALPHA and BRAVO symbols. In most cases, accuracy is slightly better with the Large symbols although the only clear difference is with the BRAVO symbols against a Complex background.

The significant interaction across background, resolution and symbol size is illustrated in Figure 8. With a Simple background accuracy, decreases and response time increases under the LR condition with Small symbols. With the other two backgrounds, accuracy decreases and response time increases in the LR condition even if Large symbols are used.

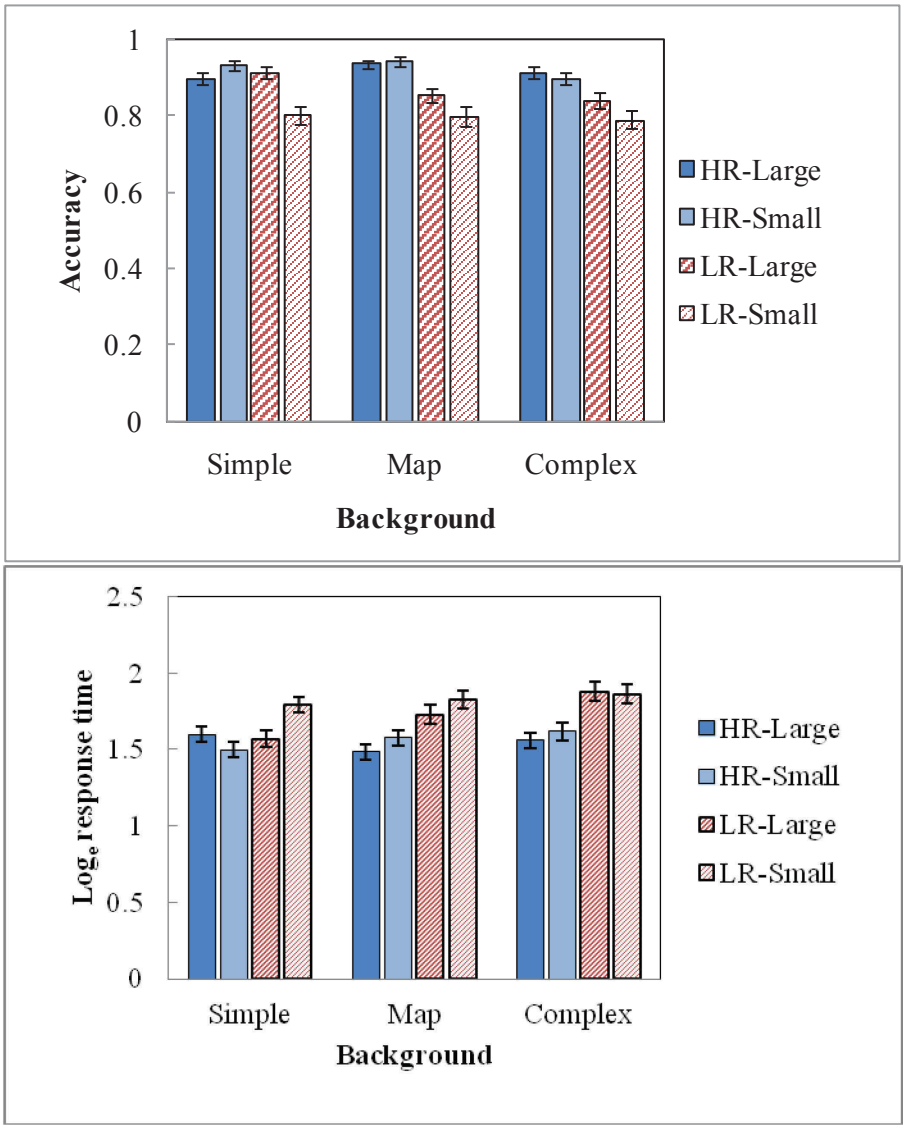


Figure 8: Accuracy and log$_e$ response time across background, resolution and symbol size.

Although there was a significant four-way interaction for accuracy, it provided little additional information about the interactions among the different independent variables. As with the three way interactions, accuracy was consistently high with the CHARLIE symbols. With the other two

symbol sets, accuracy tended to fall off under the low resolution, Small symbol conditions especially with the Map and Complex backgrounds.

Legibility

As stated earlier, the primary difference between the detection and legibility task was that participants had to be able to discriminate the numbers used to identify the unit and/or sub-unit of the soldiers represented by the symbols being displayed in the legibility task. Legibility performance was not assessed under the LR condition due to limitations in time and resources.

As can be seen in Table 8, the independent variables tended to have less effect on accuracy with the legibility task compared to the detection task. This is not surprising given that much of the differences in accuracy found with the detection task were related to lower accuracy in the low resolution conditions for the ALPHA and BRAVO symbol sets. As with the detection task, there was an overall effect of symbol set and background on response time and of symbol size on accuracy. Again, the post-hoc showed that response times were shorter for the CHARLIE symbols than the ALPHA and BRAVO symbols. In addition, response times for BRAVO were significantly shorter than for ALPHA. On the other hand, performance was significantly more accurate and shorter for the Map background relative to the others with the legibility task and performance was significantly more accurate with the small symbols. Response times tended to favour the large symbols, but the differences were not significant. All of the two-way interactions were significant, but again only for response time. Although the interaction between symbol set and background for accuracy was significant overall, a post hoc showed no significant differences among the nine combinations of background and symbol set.

Table 8: Summary of repeated measures analyses of variance for the legibility task as a function of symbol set, symbol size, and background. Results for accuracy, response time, and a multivariate analysis of both measures are shown. Column 2 shows the univariate and multivariate degrees of freedom.

Condition	Univariate / multivariate degrees of freedom	F values ($p < 0.01$)		
		Accuracy	RT	Multivariate
Symbol set (SS)	2,48 / 4,96	n.s.	103.03	19.43
Symbol size (SZ)	1,24 / 2,23	11.73	n.s.	8.31
Background (B)	2,48 / 4,96	5.13	14.86	6.24
SS *SZ	2,48 / 4,96	n.s.	10.9	4.83
SS*B	4,96 / 8,192	3.92	9.11	6.29
SZ*B	2,48 / 4,96	n.s.	18.5	6.69
SS*SZ*B	4,96 / 8,192	n.s.	n.s.	n.s.

The interactions between symbol set and background and symbol set and symbol size are shown in Figure 9. As with the detection task, a post hoc analysis showed that response times were significantly shorter across all backgrounds for the CHARLIE symbol set relative to the other two symbol sets. For the symbol set / background interaction, the only other significant effect was that

response times for ALPHA against a complex background were significantly longer than response times for ALPHA and BRAVO with a Map background and BRAVO with a Complex background. The trend was the same for the symbol set / symbol size interaction. Response times for the ALPHA symbols were significantly poorer than those for the Bravo symbols.

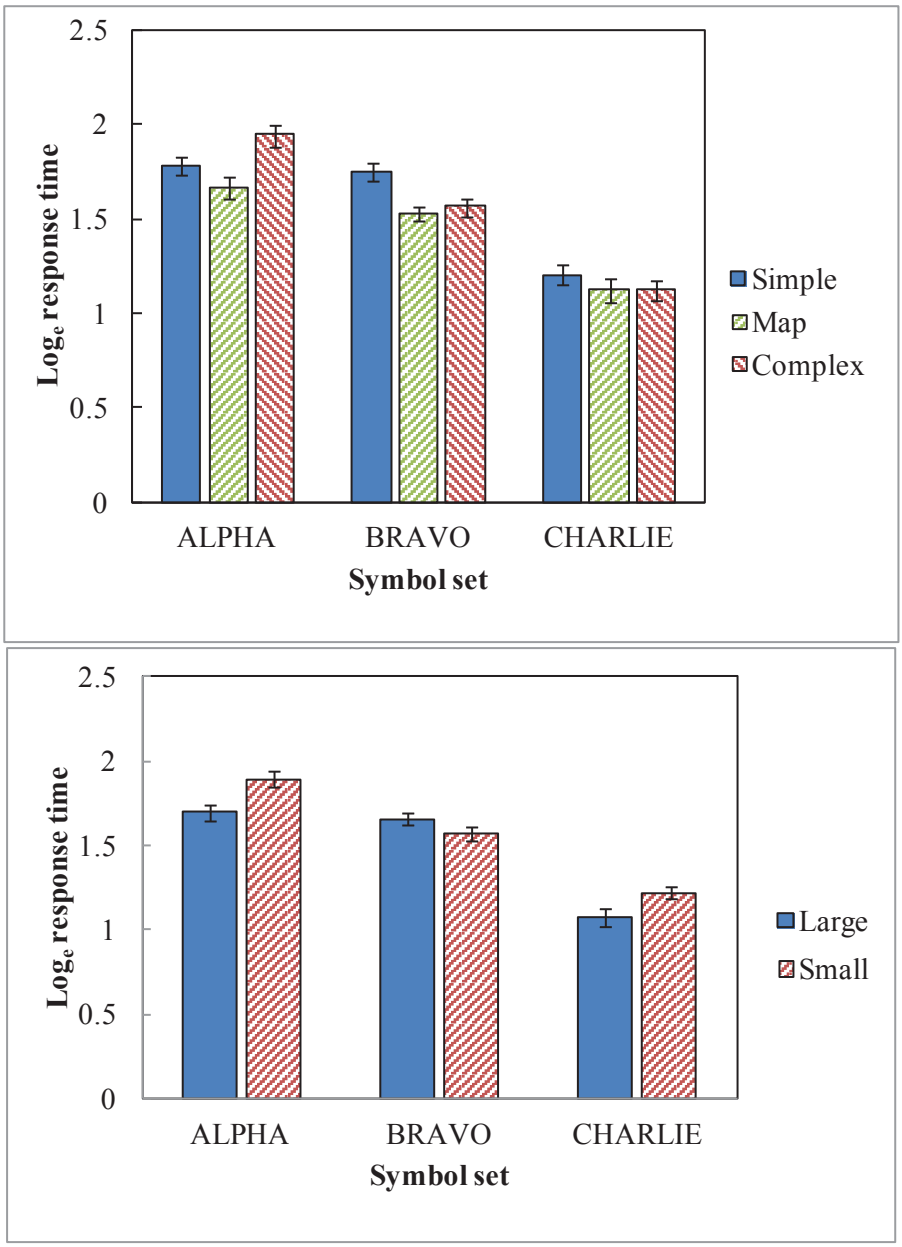


Figure 9: Log$_e$ response time as a function of symbol set and background and symbol set and symbol size.

For the background / symbol size interaction, the post-hoc supported the picture shown in Figure 10. Response times were significantly faster with Large symbols only against a Map background.

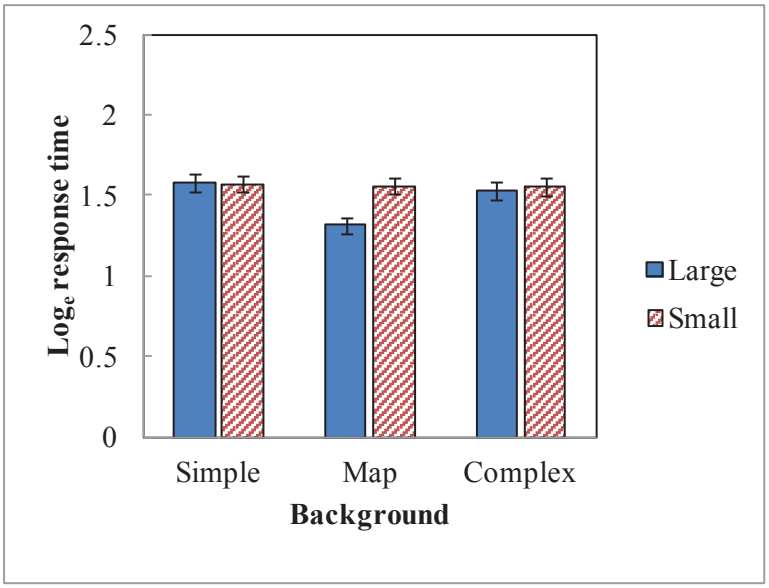


Figure 10: Log$_e$ response time as a function of background and symbol size.

Discussion

Symbol set

Based on the results, the CHARLIE symbol set was clearly superior to both the ALPHA and BRAVO sets. In addition, detectability and legibility of the CHARLIE set was not significantly affected by any of the manipulations. With a high resolution display, accuracy of the three symbol sets was similar. However, as resolution decreased, accuracy of ALPHA and BRAVO decrease significantly especially against the Complex and Map backgrounds and with the smaller symbols. Under all conditions, response times were on average more than twice as long with the ALPHA and BRAVO symbols as compared to the CHARLIE symbols (3.3 seconds on average for the CHARLIE symbols as compared to 6.6 seconds for the ALPHA and BRAVO symbols).

Thus, it would seem that any symbols for representing the dismounted soldier should use the prototype CHARLIE symbols as a starting point. The primary difference between CHARLIE and the other two sets was that all of the critical information required to identify a particular symbol was located within the symbol border. With the BRAVO symbols, in particular, information about echelon and affiliation appeared against the image background. If the background was dark, the contrast between that part of the symbol and the background was very low making symbol identification difficult. It was thought that the use of the white flag with the ALPHA symbol set would make this information more visible. However, this modification did not lead to faster response times. In fact, in the legibility task, response times for BRAVO symbols were actually faster than those for ALPHA and in the detection task, performance was similar. Thus, the use of this type of mechanism is not recommended without further evaluation.

Resolution

Even though performance with the CHARLIE symbol set was similar in both the HR and LR conditions, resolution did impact the detectability of the ALPHA and BRAVO symbols. Accuracy tended to be lower and response times longer in the low resolution conditions. One possible reason is that the echelon information was encoded using narrow lines. High spatial frequency information is more likely to be adversely affected as resolution decreases. For that reason, it is advisable to minimize the requirement to discriminate fine detail in designing symbols.

Symbol size

Increasing symbol size had a relatively small effect on performance. Primarily it helped offset the decrement in performance with low resolution displays. This finding would be consistent with the previous hypothesis that low resolution displays affect the discrimination of high spatial frequency information. Thus, if it is necessary to use a lower resolution display, symbol size should be increased. Unfortunately, this has the potential to increase clutter. Thus, it would be even more important to provide tools for decluttering the display.

Background

Since future systems will be used in a wide range of environments, the symbols must be visible over a wide range of backgrounds. Thus, the issue in comparing backgrounds was to determine the best means of minimizing the effect of background on detectability. Based on the results, the design guidelines followed in developing the CHARLIE symbol set achieved that goal. However, even with the other symbol sets, background did not have a large or consistent affect on detectability. For example, with the ALPHA set detection tended to be less accurate with a Simple background while with the BRAVO set, detection tended to be poorer with a Complex background, as might be expected. One possible reason for this was the fact that each target symbol was presented in a single location for each combination of conditions across all participants. Thus, some of the higher level interactions could have been due in part to the location of the target symbol under a specific combination of conditions instead of to the combination of independent variables under study. For example, the relatively low accuracy for the Small ALPHA symbols in the LR condition against a Simple background was due to extremely low accuracy for two symbols. If the location of the target symbol had been randomized across participants or if each participant had carried out multiple trials under each combination of conditions, with the target in different locations on each trial, there might have been a stronger and more consistent effect of background.

Unfortunately, the time and resources were not available to either prepare the additional stimuli or carry out additional trials. In future it might be preferable to focus on varying the location of the target symbol across a small number of backgrounds rather than systematically manipulating background.

Performance of individual symbols

As indicated, in the introduction, the current CHARLIE symbol set is incomplete. Symbols do not exist for all of the NATO roles and echelons of dismounted soldiers. Thus, a critical requirement is to complete the symbol set. To support this process it is useful to look at the accuracy and response times of the individual symbols. Consistent differences in performance could help inform the development of the remaining symbols. A cursory examination of the effect of the different parameters on accuracy and response time for the individual symbols indicated that accuracy of the individual symbols was relatively similar, but that there was some variability in response time. Resolution was the only parameter that had any effect on the variability in response time across the individual symbols (Figure 11). Except for Platoon Commander, the symbols with the longest response times had two or three circles. It could be that these symbols were less discriminable because they differed primarily in the number of circles. However, if that was the case, one would have expected the response times for Platoon Commander to be longer as well. Given that the response times are averaged over a wide range of backgrounds and two symbols sizes, they are presumably reasonably robust. However, at the very least, it would seem prudent to try to utilize relatively unique icons for echelon as much as possible. For example, one would expect that if symbols using the current icon for squad (Table 4) were added to the set, it would reduce the visibility of the Fire Team Leader symbol as well as symbols incorporating the Platoon and Section icons.

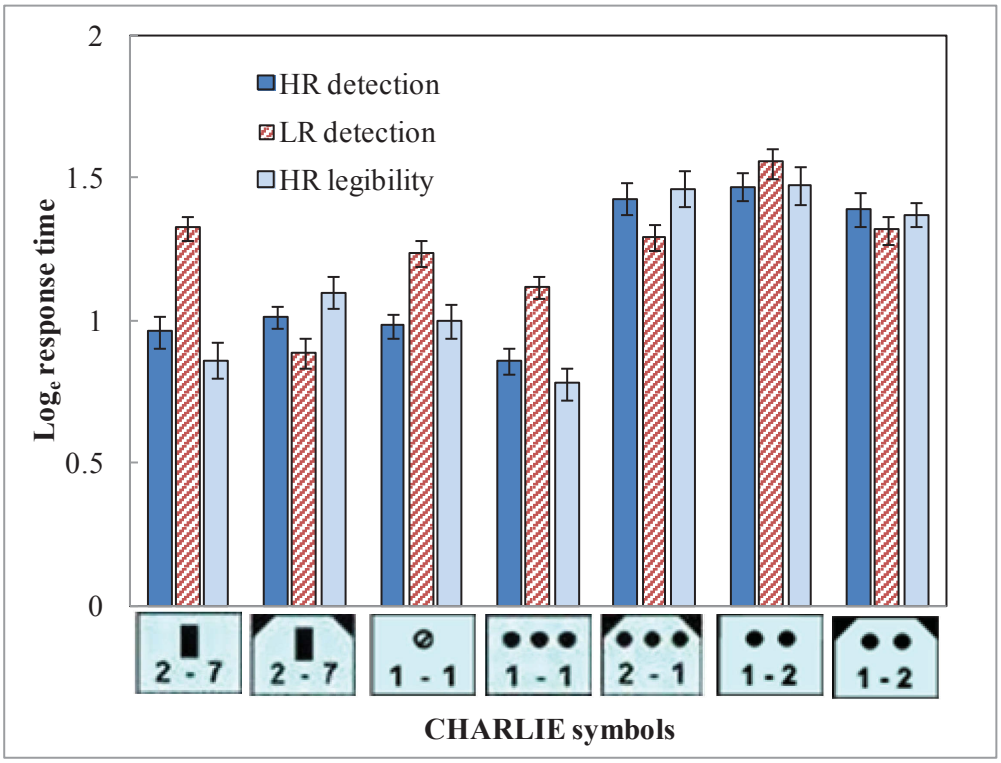


Figure 11: Log$_e$ response times for the individual target symbols in the CHARLIE symbol set in the detection (HR and LR conditions) and legibility tasks. From left to right, the symbols represent Company Commander, Company Second in Command, Fire Team Leader, Platoon Commander, Platoon Sergeant, Section Commander, and Section Second in Command.

Limitations with the current experiment

The differences across individual symbols suggest that part of the reason for the poorer performance with the ALPHA and BRAVO symbols could have been due to the number of different distractor symbols. In the detection task, the symbols for Gunnery Sergeant and Quartermaster Sergeant appeared as distractors with the ALPHA and BRAVO symbol sets, but not with the CHARLIE symbol set. Visual search experiments by Duncan and Humphreys (1989) found that search difficulty is a function of both similarity between target symbols and non target symbols and dissimilarity amongst non-target symbols. Since the number of non-target symbols was fixed, there would have been greater dissimilarity amongst the non-target symbols with the ALPHA and BRAVO symbol sets compared to the CHARLIE symbol sets. However, it is unlikely that the use of eight versus six different types of distractor symbols would account for the large differences in response time found in this study. Moreover, it is unlikely that the additional distractor symbols would lead to the pattern of results seen across the different factors studied.

Another limitation, already discussed above, is the lack of randomness in target location across participants within each combination of conditions. Given this limitation, the results of this study should be used primarily to identify the factors that are likely to have the most impact on performance. Future experiments should focus on testing this subset of factors more rigorously. Of the three factors studied, resolution appeared to have the greatest effect. Moreover, it was only resolution that impacted the performance of the individual CHARLIE symbols. For that reason, it is recommended that future studies only manipulate resolution. The default condition for the other factors should be the small symbols and complex backgrounds.

Conclusion and recommendations

At the request of NATO LCG1, DRDC Toronto conducted two studies to evaluate candidate symbol sets to represent individual dismounted soldiers. Prototype symbol sets for this purpose have been developed by several NATO nations. A heuristic evaluation of these sets indicated that none of them were entirely consistent with good human factors practice. A new set (CHARLIE) was developed that conformed more closely to human factors guidelines. An empirical evaluation of two of the symbol sets, the proposed symbol sets CHARLIE, and two variants (ALPHA and BRAVO) of a set designed by NATO LCG1, was then conducted. The results indicated that detection and discrimination of the CHARLIE symbols was significantly faster under all of the conditions tested and significantly more accurate with low resolution displays. Moreover, performance with the CHARLIE symbols was consistent across all the conditions tested (background, resolution, and symbol size).

Based on the results of this study, it is recommended that the CHARLIE symbol set be expanded to incorporate symbols that represent the full range of dismounted soldier roles and echelons. Once this has been accomplished, a modified version of the current study should be carried out. As discussed above, it should not be necessary to repeat all of the conditions used in this study. Instead, it is recommended that the study look at detection and legibility of the Small symbols against relatively complex backgrounds.

If resolution and/or increasing the number of different symbols are shown to have significant impact then methods for improving the visibility of the symbol components should be investigated. The simplest method is to increase symbol size. However, this has negative side effects including greater symbol overlap and clutter. An alternative method would be to simplify the symbols by reducing the amount of information encoded in the basic symbol. This would result in a smaller number of more discriminable symbols. Additional information could be provided on demand (by selecting the symbol or a small subset of the display) or by annotating the symbol in some way.

In addition to investigating the visibility and legibility of the larger symbol set, it will be important to assess its utility. What information, represented by these symbols, is critical to the user employing them? A better understanding of the user requirements for this type of symbology could lead to more effective designs in which the relative visibility of the different components of a symbol reflects its criticality.

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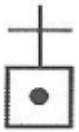
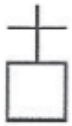
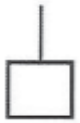
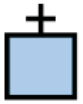
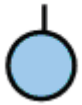
Annex A National symbol sets for individual soldiers

Country	ROLE									
	Company Com-mander	Company 2 i/c	Gunnery Sergeant	Company Quarter-master Sergeant	Platoon Com-mander	Platoon Sergeant	Section Com-mander	Section Com-mander 2 i/c	Fire Team Leader	Soldier
Belgium							 Section Chief			
Canada			 Warrant Officer	 Master Warrant Officer		 Platoon Warrant		 Corporal		
Netherlands							 1 Sergeant	 2 Corporal		 5 Private

Country	ROLE									
	Company Com-mander	Company 2 i/c	Gunnery Sergeant	Company Quarter-master Sergeant	Platoon Com-mander	Platoon Sergeant	Section Com-mander	Section Com-mander 2 i/c	Fire Team Leader	Soldier
Switzerland	 Unit Leader				 Platoon Leader		 Group Leader			 Soldier
United States Army										
United States Marine Corps										
LCG1 Proposal										

Annex B Symbols used in Experiment

The following tables show all the symbols used in the experiment. Each symbol incorporates the following dimensions:

a) Role: Does the soldier occupy an officer or enlisted role?

b) Echelon: At what echelon is the soldier employed (Company, Platoon, or Section/Squad)?

c) Affiliation: What is the affiliation of the unit that employs the soldier?

For BRAVO and ALPHA, role is indicated by the number of diagonal lines inside the blue circle. Echelon is denoted by lines and cross lines extending above the circle and affiliation by the convention of unit of sub-unit (e.g. 13 indicates the soldier is a member of One Platoon, Three Section) beside the echelon component. For CHARLIE, a regular frame indicates an officer while an enlisted role is denoted by the angled corners. Echelon is indicated by the icon inside the rectangle and affiliation by the two numbers, separate by a dash, below the icon. The same unit of sub-unit convention is used. A wider range of echelons (e.g. gunnery sergeant) exist for BRAVO than CHARLIE. For consistency, target symbols were restricted to the echelons available in the CHARLIE set. However, the additional BRAVO symbols were used as distractors.

For the legibility task, at least two versions of each target symbol, representing the same position in different units (e.g. Section and Platoon), were generated. The tables also show the symbols available in the Large and Small version of each set.

Table B9: Available ALPHA symbols

NATO position	Large symbols					Small symbols				
Company Commander										
Company Second-in-Command										
Fire Team Leader										
Gunnery Sergeant										
Platoon Commander										
Platoon Sergeant										
Quartermaster Sergeant										
Section Commander										
Section Second-in-Command										

Table B10: Available BRAVO symbols

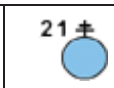
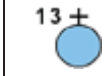
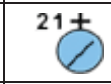
NATO positions	Large symbols					Small symbols			
Company Commander									
Company Second-in-Command									
Fire Team Leader									
Gunnery Sergeant									
Platoon Commander									
Platoon Sergeant									
Quartermaster Sergeant									
Section Commander									
Section Second-in-Command									

Table B11: Available CHARLIE symbols

NATO position	Large symbols			Small symbols		
Company Commander						
Company Second-in-Command						
Fire Team Leader						
Platoon Commander						
Platoon Sergeant						
Section Commander						
Section Second-in-Command						

List of symbols/abbreviations/acronyms/initialisms

DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
LCG1	Land Capability Group 1
NATO	North Atlantic Treaty Organization
R&D	Research & Development

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(U) The North Atlantic Treaty Organization (NATO) Land Capability Group 1 (LCG 1) has identified a need to develop and validate symbology for the individual soldier that can be displayed on a wide range of digital displays. Prototype symbology sets for this purpose have been developed by several NATO nations. A heuristic evaluation of these sets indicated that none of them were entirely consistent with good human factors practice. A new set (CHARLIE) was developed that conformed more closely to human factors guidelines. To further evaluate the most suitable symbology, an empirical assessment was carried out. Two different sizes of three prototype symbol sets were evaluated against backgrounds composed of digital photographic images of differing complexity and digitized paper maps under two different display resolutions. The symbol sets evaluated were the CHARLIE set discussed above, and two variants (ALPHA and BRAVO) of a set designed by NATO LCG1. The symbols were evaluated using a visual search task with accuracy and speed of response as the measures of performance. The results indicated that detection and discrimination of the CHARLIE symbols was significantly faster under all of the conditions tested and significantly more accurate with low resolution displays. Moreover, performance with the CHARLIE symbols was consistent across all the conditions tested (background, resolution, and symbol size).

(U) Le 1er Groupe sur les capacités terrestres (LCG 1) de l'Organisation du Traité de l'Atlantique Nord (OTAN) a cerné la nécessité de mettre au point et de valider une symbologie du soldat qui peut être affichée sur une vaste gamme d'écrans numériques. Plusieurs pays de l'OTAN ont développé des prototypes d'ensembles de symboles à cette fin. Une évaluation heuristique de ces ensembles a indiqué qu'aucun d'eux n'était tout à fait conforme aux bonnes pratiques ergonomiques. On a élaboré un nouvel ensemble (CHARLIE) qui respectait plus étroitement les lignes directrices de l'ergonomie. Pour évaluer davantage la symbologie la plus appropriée, on a procédé à une évaluation empirique. Deux tailles différentes de trois prototypes d'ensembles de symboles ont été évaluées sur des fonds composés d'images photographiques numériques de complexité différente et de cartes papier numérisées, selon deux résolutions d'affichage différentes. L'évaluation a porté sur l'ensemble CHARLIE susmentionné et sur deux variantes (ALPHA et BRAVO) d'un ensemble conçu par le LCG 1 de l'OTAN. On a évalué les symboles au moyen d'une recherche visuelle en utilisant comme mesures de rendement la précision et la vitesse de réponse. Les résultats ont indiqué que la détection et la discrimination des symboles CHARLIE étaient beaucoup plus rapides dans toutes les conditions d'essai et beaucoup plus précises avec des affichages à basse résolution. Par ailleurs, les symboles CHARLIE ont donné lieu à un rendement uniforme dans toutes les conditions d'essai (fond, résolution et taille des symboles).

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(U) symbology; NATO; Land Forces; maps; resolution; symbol size; digital imagery; background complexity; legibility; visibility; visual search; accuracy; response time

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